● *Clinical Note*

LUNG ULTRASOUND IN CHILDREN WITH COVID-19: PRELIMINARY FINDINGS

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Abstract—Recent evidence indicates the usefulness of lung ultrasound (LUS) in detecting coronavirus disease 19 (COVID-19) pneumonia. However, no data are available on the use of LUS in children with COVID-19 pneumonia. In this report, we describe LUS features of 10 consecutively admitted children with COVID-19 in two tertiary-level pediatric hospitals in Rome. LUS revealed signs of lung involvement during COVID-19 infection. In particular, vertical artifacts (70%), pleural irregularities (60%), areas of white lung (10%) and subpleural consolidations (10%) were the main findings in patients with COVID-19. No cases of pleural effusions were found. According to our experience, the routine use of LUS in the evaluation of children with suspected or confirmed COVID-19, when performed by clinicians with documented experience in LUS, was useful in diagnosing and monitoring pediatric COVID-19 pneumonia, reducing unnecessary radiation/sedation in children and exposure of health care workers to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). (E-mail: danilobuonsenso@gmail.com)   © 2020 Published by Elsevier Inc. on behalf of World Federation for Ultrasound in Medicine & Biology.

Key Words: **Lung ultrasound, Coronavirus disease 19 (COVID-19), Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), Children.**

INTRODUCTION

Initially described in China in December 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread all over the world, infecting more than 1 million people and causing thousands of deaths (Zhu et al. 2020). Humans of all age groups are susceptible, including the youngest. Although currently pediatric coronavirus disease 19 (COVID-19) appears to be less severe compared with the adult form, children are by no means spared. Several case series (Dong et al. 2020; Lu et al. 2020b; Qiu et al. 2020; Tagarro et al. 2020) have documented that COVID-19 can affect children of all ages, from newborns to adolescents. Importantly, COVID-19 pneumonia has also been described in asymptomatic or pauci-symptomatic children (Dong et al. 2020; Lu et al. 2020a; Qiu et al. 2020).

Although a nasopharyngeal swab is required for a definitive etiologic diagnosis, this test has limitations, particularly because of its low sensitivity (Wang et al. 2020). For this reason, several authors have suggested the use of chest computed tomography (CT) not only for diagnosis of COVID-19 pneumonia, but also as a screening tool for the diagnosis of COVID-19 infection in epidemic settings, as CT has been reported to have better diagnostic sensitivity than nasopharyngeal swab (Ai et al. 2020). Conversely, Rubin et al. (2020) suggested an appropriate use of imaging, selecting those patients that might benefit from the adjunctive information contained in images. However, CT scan should not be routinely used in specific age groups, such as pregnant women (Moro et al. 2020) and children. Moreover, COVID-19 has become a global disease, logistic difficulties or unavailability of CT scan in low- and medium-resource settings must be considered. On the other hand,

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chest X-ray does not have sufficient sensitivity and specificity for detecting COVID-19 pneumonia to be considered as an alternative tool to CT scan.

In this context, recent evidence has indicated the usefulness of lung ultrasound (LUS) in detecting COVID-19 pneumonia (Buonsenso et al. 2020a; Kalafat et al. 2020; Smith et al. 2020). In particular, both Chinese (Peng et al. 2020) and Italian (Soldati et al. 2020a, 2020b) task forces on the use of LUS in COVID-19 have provided the physical bases and LUS patterns in COVID-19 patients, suggesting that LUS can be a useful tool to diagnose and monitor COVID-19 pneumonia. However, no data are available on the use of LUS in children with COVID-19 pneumonia.

For this reason, we performed this study with the aim of evaluating the role of LUS in children with COVID-19.

METHODS

We conducted an observational study analyzing LUS patterns in consecutively admitted children with COVID-19 infection in two tertiary level pediatric hospitals in Rome, beginning March 15, 2019. All patients with swab-confirmed COVID-19 infection who underwent LUS within 12 h from admission were included. The use of LUS in the evaluation of children with respiratory infection has been approved by the ethics committees of our institutions. Informed consent was obtained from each parent/guardian. LUS was performed with a wireless pocket device connected to a probe, which were placed in single-use plastic covers (ATL Milano, Milan, Italy), as described by Buonsenso et al. (2020b). LUS was performed in patients in the sitting position, and all lung areas were scanned, as suggested by Soldati et al. (2020a). The two operators responsible for LUS are pediatricians with more than 5 y of experience in point-of-care ultrasound and several publications in this setting (Buonsenso et al. 2020a, 2020b, 2020c, 2020d; Musolino et al. 2019a, 2019b). The LUS patterns looked for were those described by Soldati et al. (2020a): pleural irregularities, subpleural consolidations, vertical artifacts, patchy areas of white lung, pleural effusions.

RESULTS

We evaluated 10 consecutively admitted children with COVID-19 with positive real-time polymerase chain reaction on nasopharyngeal swabs. LUS was performed on admission when real-time polymerase chain reaction results were still pending. Clinical, laboratory and imaging parameters and outcome data are summarized in Table 1. The median age was 11 y (interquartile range: 4 y 9 mo to 15 y). Previous medical history was unremarkable in all cases. All patients were symptomatic at the time of admission to the hospital, with fever in 80%, cough in 50% and diarrhea in 20% of cases. Anosmia (10%), arthralgia (30%), chest pain

(20%) and headache (20%) were also reported. Results of laboratory investigations were within normal ranges according to patient age in all cases, with the exception of two children: one had leukopenia, and the other had a slightly altered C-reactive protein level. All children recovered, and none of them required pediatric intensive care admission.

In all symptomatic cases, LUS revealed signs of lung involvement during COVID-19 infection. In particular, vertical artifacts, areas of white lung and subpleural consolidations and pleural irregularities were the main findings in pediatric COVID-19 pneumonia. There were no cases of pleural effusions. In one case, CT scan was performed, and LUS findings correlated well with chest CT (Fig. 1). Patient 5 was admitted for complex afebrile seizures, so to minimize the child's movements and reduce the risk of nosocomial spread, the lung imaging of choice was magnetic resonance imaging (MRI) as an extension of the brain MRI dictated by his admitting diagnosis. His pulmonary MRI revealed signs of pneumonia, confirming the LUS findings. Two patients underwent chest X-ray that revealed non-specific, diffuse interstitial thickening.

DISCUSSION

In this study, we found that LUS is able to detect lung pathology in children with confirmed COVID-19. In particular, LUS patterns seen in our patients were mainly vertical artifacts, pleural irregularities, subpleural consolidations and patchy areas of white lung. Since our proposal for more frequent use of LUS in COVID-19 patients (Buonsenso et al. 2020b) and the first description of a patient with vertical artifacts, pleural irregularities and subpleural consolidations (Buonsenso et al. 2020d), growing evidence in adults has revealed that LUS is able to detect COVID-19. during SARS-CoV-2 infection is much more frequent in adults than in children; however, the main patterns are similar to those we described in children. Both Italian sonographers and the Chinese Critical Care Ultrasound Study Group (Peng et al. 2020) described the same patterns in adults. Importantly, LUS has been documented as an important tool particularly in moderate to severe pneumonia (Lu et al. 2020b) and, mainly, in the monitoring of lung disease (Moro et al. 2020).

The finding that LUS is able to detect COVID-19 pneumonia in children has clinical implications. The Chinese Task Force for Pediatric COVID-19 proposed a severity classification, defining children as asymptomatic, mild, moderate, severe or critical cases (Dong et al. 2020). In particular, the "moderate" stage is based on clinical criteria (pneumonia with fever and cough, in the absence of signs of hypoxemia) *and/or* radiologic criteria, as "some cases may have no clinical signs and symptoms, but chest CT shows lung lesions, which are subclinical" (Dong et al. 2020). In

Table 1. Main Clinical, Laboratory and Imaging Findings in a cohort of pediatric patients with COVID-19.

	Total	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Patient 9	Patient 10
Age, y	11 (4 y 9 mo−15 y)	13	1	15	1	15	6	16	10	12	7
Sex	60% Male	M	F	F	F	M	M	F	M	M	M
Symptoms											
Fever	80%	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Cough	50%	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No
Diarrhea	20%	No	No	No	No	No	No	No	Yes	Yes	No
Other		No	No	Chest pain	No	Seizure (not related)	No	Chest pain Anosmia	Arthralgia Headache	Arthralgia Headache	Arthralgia
WBCs/mm^3	5520 (4550−7345)	5400	14,170	7000	—	7460	5640	2790	4440	4900	—
L/mm^3	2055 (1470−2922)	1970	5870	2140	—	1040	3150	1340	1860	2240	—
CRP mg/L	1,6 (0.375−5.05)	5.5	33.6	2.4	—	0.8	0.6	3.7	0.3	0.3	—
X-Ray		Not performed	Not performed		Not performed	Not performed	Not performed		Not performed	Not performed	Not performed
Localization				Left				Bilateral			
Consolidation				No				No			
Interstitial				Yes				Yes			
Effusion				No				No			
CT scan		Not performed	Not performed	Not performed	Not performed	MRI*	Not performed		Not performed	Not performed	Not performed
Localization						Left		Left			
Consolidation						Yes		No			
Ground glass						No		Yes			
Interstitial						No		No			
Effusion						No		No			
Lung ultrasound											
Localization	70% Bilateral	Monolateral	Bilateral	Bilateral	Bilateral	Monolateral	Bilateral	Monolateral	Bilateral	Bilateral	Bilateral
Pleural irregularities	60%	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Vertical artifacts	70%	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
White lung	10%	No	No	No	No	No	No	Yes	No	No	No
Consolidations	10%	Yes	No	No	No	No	No	No	No	No	No
Pleural effusion	0%	No	No	No	No	No	No	No	No	No	No

CRP = C-reactive protein; CT = computed tomography; L/mm^3 = Lymphocite/mm^3; MRI = magnetic resonance imaging; WBCs = white blood cells.
Variables are expressed as a percentage or median (interquartile range).
* This patient underwent lung MRI, as brain MRI was necessary because the child had complicated afebrile seizures.
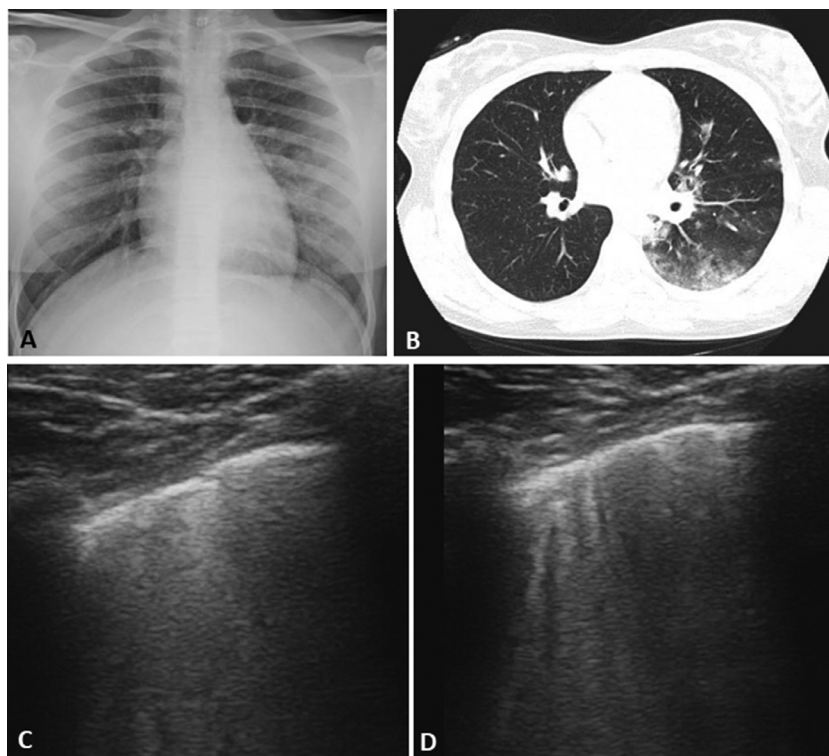
Fig. 1. Main imaging findings in patient 7 with confirmed COVID-19. (a) Chest X-ray reveals diffuse interstitial disease, with the left lobe more involved. (b) Computed tomography scan reveals ground glass and subpleural consolidations. (c, d) Lung ultrasound reveals patchy areas of white lung (c) and long, bright, thick vertical artifacts (d).

fact, in all the large series of pediatric COVID-19 described in China (Dong et al. 2020; Lu et al. 2020; Qiu et al. 2020), the authors routinely used CT scan to determine the severity of the disease. This has caused clinicians and researchers from the rest of the world to overuse CT scan in children, even when they are asymptomatic or pauci-symptomatic. However, to date there is no evidence that diagnosis and treatment decisions based on CT scans improve outcomes in pediatric COVID-19 infection. Moreover, CT scanning should be used parsimoniously in the pediatric age group because of their increased sensitivity to radiation exposure and because it may require sedation. In fact, international guidelines state that history and examination are the main determinants of pneumonia severity and level of care, reserving imaging to compromised children requiring admission on clinical grounds (Bradley et al. 2011). Importantly, the large number of asymptomatic and mild pediatric cases of COVID-19 (Dong et al. 2020; Lu et al. 2020; Qiu et al. 2020; Tagarro et al. 2020) described so far confirms that radiologic imaging should not be routinely used. In our series, only in two cases were chest X-ray and CT scan were performed. The small number of patients undergoing traditional imaging is owing mainly to the long experience of our institutions in performing LUS, which is currently routine practice in children with respiratory symptoms that we see in our centers. In this context, thanks to the already proven

accuracy of LUS in detecting pediatric pneumonia of any etiology (Pereda et al. 2015; Berce et al. 2019; Musolino et al. 2019a; Supino et al. 2019; Buonsenso et al. 2020c), and in the light of our observational findings, we suggest the routine use of bedside LUS in children with suspected or confirmed COVID-19. As previously suggested (Buonsenso et al. 2020b), LUS would also allow the same pediatrician to both perform the physical examination and collect the lung images, with the advantage of reducing the exposure of other health care workers to infected patients. Moreover, a Multinational Consensus Statement from the Fleischner Society (Rubin et al. 2020) provided five main and three additional recommendations intended to guide medical practitioners in the use of chest X-rays and CT in the management of COVID-19. They concluded, with current knowledge, that (i) imaging is not routinely indicated in patients with suspected COVID-19 and mild clinical features unless they are at risk for disease progression; (ii) imaging is indicated in a patient with COVID-19 and worsening respiratory status; and (iii) in a resource-constrained environment, imaging is indicated for medical triage of patients with suspected COVID-19 who present with moderate-severe clinical features and a high pre-test probability of disease. These guidelines support the appropriate use of imaging and, in this context, point-of-care tools such as LUS, particularly in children, who usually have milder manifestations of COVID-19.

CONCLUSIONS

The routine use of LUS in the evaluation of children with suspected or confirmed COVID-19, if performed by clinicians with documented experience in LUS, could be a useful tool in diagnosing and monitoring COVID-19 pneumonia, while reducing unnecessary radiation/sedation in children and exposure of health care workers to SARS-CoV-2.

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